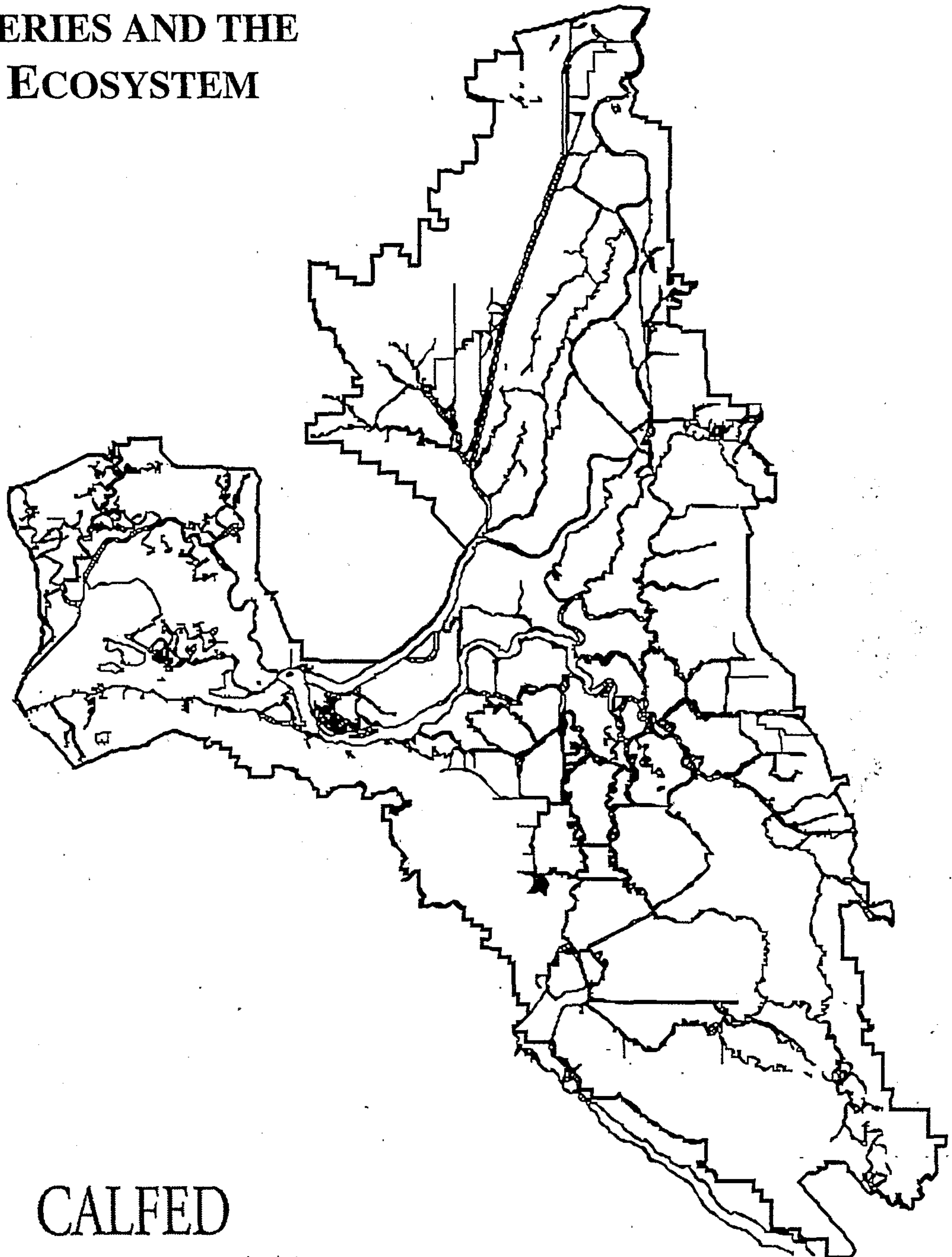
CALFED Bay-Delta Program

Draft Assessment Methods for Fisheries and the Aquatic Ecosystem



CALFED
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PROGRAM

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C–045172

C-045172

TABLE OF CONTENTS

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METHODS FOR FISHERIES AND THE AQUATIC ECOSYSTEM ASSESSMENT

INTRODUCTION

In June 1996, the CALFED Bay-Delta Program (CALFED) began the selection of programmatic impact assessment methods for the fisheries and aquatic ecosystem section of the Programmatic Environmental Impact Report/Environmental Impact Statement (EIR/EIS). A team of agency and stakeholder fishery experts was invited to participate in the process. This report summarizes the points of general agreement reached by the team, including identification and definition of key ecosystem functions, a refined list of assessment variables and their definitions, definition of geographic regions, a list of representative species and information supporting their selection, and a description of methods and relationships that will be applied in the programmatic impact assessment.

Information provided by team participants both during the team meetings and by written comments has substantially influenced the process for selecting methods. The most important and consistently restated concern is that an evaluation of the alternatives should be based on known and defensible relationships that are important with regard to ecosystem function and structure. This report reflects efforts to address this concern.

The initial focus of the team meetings was on specific relationships between selected fish species and specific environmental conditions. In response to suggestions by participants in the assessment process, the overall method for assessing programmatic impacts has been modified to focus on an expanded array of aquatic ecosystem structures and functions.

BACKGROUND

The major ecosystem quality objectives of CALFED are to improve and increase aquatic and terrestrial habitats and to improve ecological functions in the San Francisco Bay/Sacramento-San Joaquin River Delta (Bay-Delta) to support sustainable populations of diverse and valuable plant and animal species. Alternatives included in the Programmatic EIR/EIS are structured to meet these and other objectives relating to water quality, water supply reliability, and system vulnerability. The different alternatives will have varying effects on the aquatic ecosystem. The programmatic impact assessment must identify potential changes in the aquatic ecosystem, both beneficial and adverse, under each alternative relative to the No-Action Alternative and existing conditions. In addition, the programmatic impact assessment must identify differences between the alternatives and provide information to assist decision makers in selection of a preferred program.

OVERVIEW OF THE PROGRAMMATIC IMPACT ASSESSMENT METHODS

The pathway for linking CALFED actions to changes in the aquatic ecosystem is shown in Figure 1. Actions affect assessment variables that, in turn, affect ecosystem functions that relate directly to the impacts and benefits to the aquatic ecosystem.

CALFED alternatives will implement interrelated actions to restore and improve ecosystem function and structure (Figure 1). Flow-related actions include reservoir operations and diversions. Structure-related actions include relocation and consolidation of diversions, construction and operation of barriers, fish screen construction and improvements, and operation of multilevel release structures to provide for water temperature needs. Habitat-related actions will improve water quality and restore habitat. Species-management actions include fishing regulation, hatchery production, removal of predators, and restrictions on introduction of non-native species.

ASSESSMENT VARIABLES

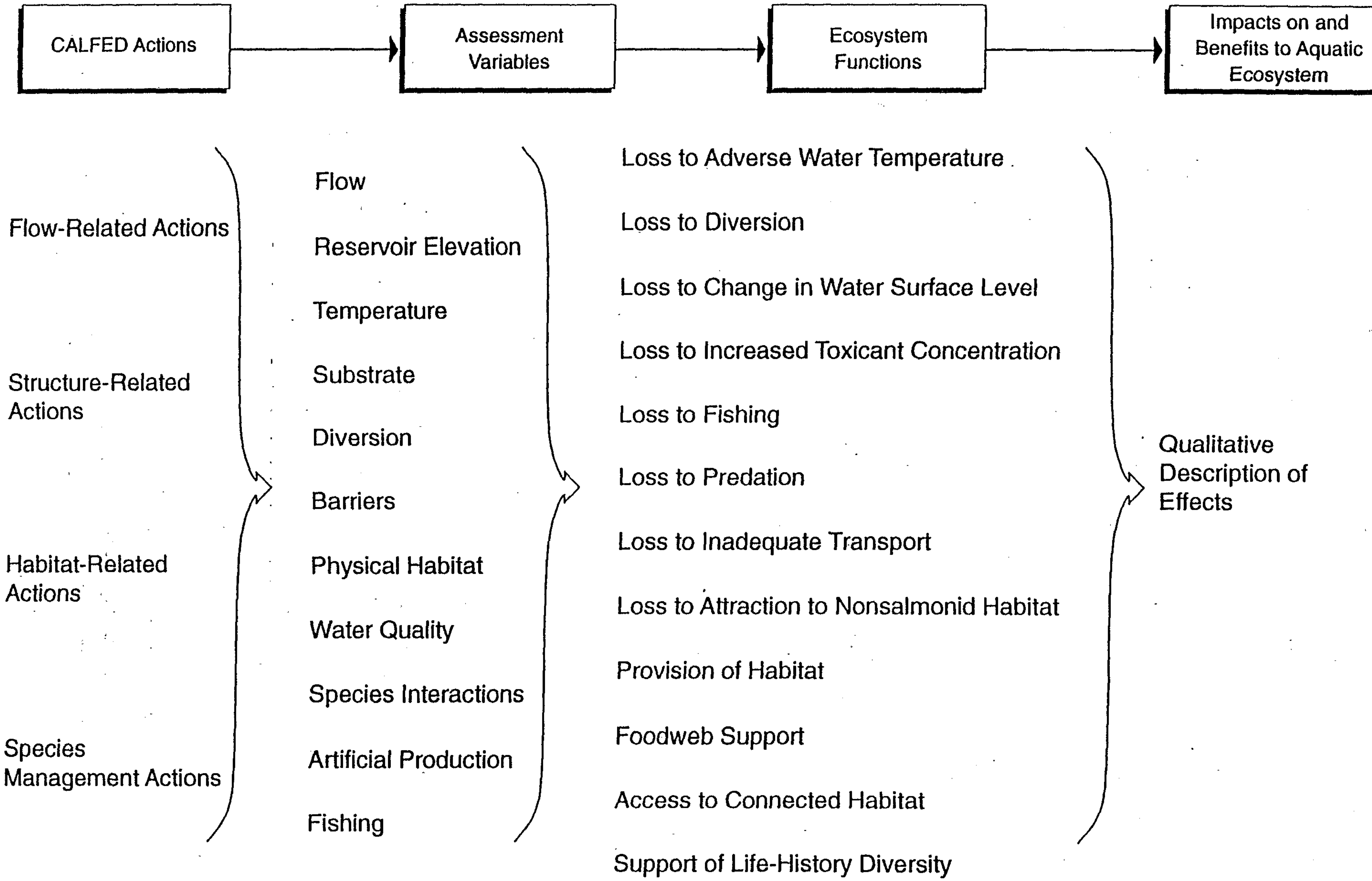
Assessment variables represent structural components of the aquatic ecosystem including physical, chemical, and biological features. Ecosystem structure is reflected in the interrelationship and organization of these components. Change in the assessment variables affects ecosystem functions and associated species within the aquatic ecosystem. Definitions of assessment variables are provided below.

Flow

Flow includes several parameters directly related to flow volume in rivers, streams, and the Bay-Delta estuary. The parameters include instream flow, net channel flow, tidal flow, and estuarine salinity.

INSTREAM FLOW. Instream flow is the rate of water movement past a specific point in rivers and streams. Instream flow is affected by weather, reservoir operations, diversions, tributary inflow, groundwater and drainage.

NET CHANNEL FLOW. Net channel flow is the rate of water movement past a specific point in the Bay-Delta estuary, not including tidal flow. Net flow in a Delta channel is affected by weather; tides; tributary inflow, including effects of upstream reservoir operations; diversions;



CALFED BAY-DELTA PROGRAM

Figure 1
Pathway for Linking CALFED Actions to Impacts and Benefits

C-045176

groundwater; flow division to Delta channels, including the effects of barriers and channel morphology; drainage; and potential discharge from future in-Delta water storage facilities. Commonly calculated net flows include Delta inflow, San Joaquin River flow past Jersey Point, and Delta outflow.

TIDAL FLOW. Tidal flow is the average channel flow attributable to ebb or flood tides, not including net flow. Variables related to tidal flow include water surface elevation, tidal excursion (i.e., movement of a mass upstream and downstream with the ebb and flood tides), and tidal prism (i.e., the volume of water that moves past a location as the result of a change in tidal stage). Local factors affecting tidal flow include morphology of the tidal basin, weather, and Delta inflow.

ESTUARINE SALINITY. Estuarine salinity is measured as concentrations, electrical conductivity units, and geographical location. Estuarine salinity is a function of mixing ocean salinity with freshwater inflow and does not include land-derived salinity, which is discussed under "Water Quality". Delta outflow, tidal flow, and estuary morphology affect the distribution of salinity in the estuary.

Reservoir Water Surface Elevation

Reservoir water surface elevation refers to water surface elevation at a specific time. Reservoir water elevation is a function of reservoir inflow including factors affecting instream flow; outflow as affected by reservoir operations, groundwater percolation, evaporation, and reservoir morphology.

Water Temperature

Water temperature refers specifically to the temperature of water in stream channels, including water released from storage reservoirs. Temperature does not include discharge of cooling water from electricity-generating plants or other facilities (discussed under "Water Quality"). Water temperature is affected by weather; reservoir operations, including operation of multilevel release structures; flow; tributary inflow; groundwater; and physical habitat including shading by riparian vegetation.

Substrate

Substrate is defined by physical composition including particle size and shape, chemical composition, density, erodibility, permeability, organic content including benthic organisms such as Asian clams, and stability. Substrate is affected by erosion; deposition; transport processes that are a function of flow; physical habitat; barriers to movement of material such as dams; biological activity (e.g., burrowing organisms); source materials; and human actions including gravel cleaning, gravel addition and dredging.

Diversions

Diversion is the volume of water removed from a water body by pumps, siphons, and gravitational flow. Diversions reduce instream and net flows. Diversion facilities have structural components related to channel morphology, intake design and size, fish screens, debris screens, pilings, and other structures associated with protecting the diversion facility and facilitating operations. The effects of diversions and diversion facilities on fish and the aquatic ecosystem are determined by flow; diversion volume; facility design including fish screens; facility location; channel morphology; water quality; and species interactions such as predation.

Barriers

Barriers are any structures that direct or influence the movement of organic and inorganic material along specific pathways. Barriers include dams; temporary physical obstructions of rock and other materials; gated structures; acoustical barriers; electrical barriers; air-bubble barriers; and louvered barriers. Barriers may affect movement of organisms without affecting flow of other material. Barriers are sometimes associated with diversion facilities and the effects of barriers and diversions may be difficult to separate. The effects of barriers are determined by flow, ratio of the flow division, facility design, facility location, channel morphology, and species interactions such as predation.

Physical Habitat

Physical habitat represents the shape and form of the ecosystem including surface contours; elevation; gradient; and surface features such as trees, woody debris, rocks, boulders and bridge abutments. For reservoirs, physical habitat includes shoreline circumference; surface area; depth; depth contours; rock outcroppings; woody debris; and vegetation. For rivers and streams, physical habitat includes channel pattern (braided, meandering, or straight); width; depth; meander geometry; cross-sectional profiles; riffle-to-pool ratios; boulders and rock outcroppings; woody debris; and vegetation.

Physical habitat also includes inlets and outlets, channels, islands, fetch, and exposure. Human-created features such as bridge abutments, riprap, gabions, pilings, piers, boat ramps, docks, and artificial reefs are also part of physical habitat. Physical habitat is affected over the long term by weather, geology, and geologic events, and over the short term by weather, flow, biological processes, and human modification including dredging, levees and bank protection.

Water Quality

Water quality is a broad category that includes chemical, physical, and biological characteristics of water that may be attributable to natural and human-induced conditions. Water quality is influenced by municipal and industrial discharge; agricultural and urban runoff; direct application of pesticides; and dredging or filling operations. Accretion of groundwater in river flow may also affect water quality by altering dissolved oxygen levels and water temperature and introducing nutrients and toxicants. Other factors affecting water quality include flow, substrate, physical habitat, and other physical, chemical, and biological processes.

AGRICULTURAL SALINITY. Agricultural salinity originates from dissolved salts in agricultural runoff.

THERMAL POLLUTION. Electricity-generating plants, sewage treatment plants and other facilities; and agricultural return flows discharge water at temperatures that may exceed the temperature of the receiving water. Discharge from future in-Delta water storage facilities could also exceed the temperature of the receiving water.

DISSOLVED OXYGEN. Low dissolved-oxygen levels may result from the discharge of organic material such as treated sewage to Delta channels. Changes in dissolved oxygen levels in rivers and streams may result from reservoir discharge drawn from anoxic reservoir strata, reservoir discharge that supersaturates oxygen levels, and accretion of groundwater.

NUTRIENT AVAILABILITY. Inorganic nutrients enter the aquatic ecosystem through agricultural runoff and sewage discharge. Nutrients can also enter the ecosystem through natural processes associated with physical (e.g., flood events that inundate terrestrial and wetlands habitats, natural runoff from storm events); chemical (e.g., dissolution of substrates); and biological (e.g., organic decomposition) processes.

TOXICANTS. Toxicants have acute and chronic effects and therefore reduce the survival of fish and other aquatic organisms. Toxicants include pesticides, metals, and other chemicals that enter the aquatic ecosystem through agricultural runoff, direct application (e.g., aquatic weed control), industrial discharge, dredging, mine drainage, sewage discharge, and urban runoff.

TRANSPARENCY. Transparency is the ability of light to penetrate water. Transparency is a function of the concentration and the chemical and physical properties of inorganic and organic sediments, algae, other organic particles, and dissolved materials. Natural (e.g., flow- and wind-driven mixing and erosion, decomposing vegetation, and algal populations) and human-induced processes (e.g., dredging, dredge disposal, sewage discharge, and boat wakes) affect transparency.

Species Interactions

Species interactions depend on a broad range of biological factors. Species interactions may change substantially in response to other changes in the assessment variables discussed above.

PREDATION. Predation occurs naturally; however, fish and other aquatic organisms that are already stressed by toxicants, elevated water temperature, turbulence created by barriers, and other factors may be more susceptible to predation and therefore to additional mortality. Predation may also increase with the introduction of non-native species.

COMPETITION. Competition occurs when the use of a resource such as food or habitat by one individual reduces the availability of the same resource for another individual. Competition occurs within a species population and between species. As with predation, fish and other aquatic organisms already stressed by other factors may be less able to compete for limited resources, and species survival could decline. The introduction of non-native species with resource needs similar to those of native species may increase competition for limited resources.

DISEASE. Disease refers to fungi, bacteria, viruses, and other pathogens that may limit species population abundance. The pathogens may be natural or introduced, and the effects may vary depending on interactions with other assessment variables.

NON-NATIVE PLANTS. Introduction of non-native plants to aquatic habitats may affect species population abundance by modifying substrate, physical habitat, water circulation, water quality, and changing species interactions.

Harvest

Harvest includes commercial fishing, sport fishing, and illegal fishing activities that cause or contribute to the death of individuals in a species population.

Artificial Production

Artificial production is the human-aided production of a species in facilities, such as fish hatcheries and rearing pens, that are isolated to some degree from the natural ecosystem. The produced individuals are released to supplement wild populations and provide fishing opportunities.

ECOSYSTEM FUNCTIONS

Ecosystem functions include complex patterns of transfer, change, use, and accumulation of inorganic and organic materials, including chemicals and toxicants. These substances may be transferred between and within local ecosystems. Definitions of ecosystem functions for the biotic elements of the aquatic ecosystem are provided below.

Loss to Adverse Water Temperature

Adverse water temperature, for different species or life stages, may exceed metabolic tolerances and cause mortality. Water temperature is a primary assessment variable; however, there are interrelated assessment variables that affect water temperature including flow, reservoir water elevation, barriers, water quality, and physical habitat. Each of these must be considered in the evaluation of the effects caused by changes in water temperature. In the Sacramento-San Joaquin basin, water temperature is primarily a concern for coldwater species such as chinook salmon and steelhead trout.

Loss to Diversion

Diversions cause mortality through entrainment, impingement on fish screens or other structures associated with the diversion facility, abrasion, stress from handling, and increased predation. The variables considered in the assessment of loss to diversions are diversion volume, fish screen design, handling procedures, source-flow volume, estuarine salinity, barriers, physical habitat, and species interactions such as predation.

Loss to Change in Water Surface Level

Change in water surface level may cause mortality by exposing nests, stranding individuals, reducing or eliminating cover, and other factors. Effects of change in water surface level is assessed for streams, rivers, and reservoirs. The assessment variables considered in the assessment of loss to change in water surface level for streams and rivers are flow, substrate, physical habitat, and species interactions. The assessment variables for reservoirs are reservoir water elevation, substrate, physical habitat, and species interactions.

Loss to Toxicants

Toxicants are poisonous substances that cause the death of organisms. The assessment variables considered in the assessment of loss to toxicants are flow and water quality. Increased flow reduces the concentration of toxicants by diluting them. Reduced application of potential toxicants and actions to clean up point and non-point sources reduce input to rivers and streams reduces the concentration of toxicants affecting aquatic organisms.

Loss to Harvest

Harvest causes mortality by removing organisms from the ecosystem or by increasing stress on organisms, increasing stress-related mortality. The primary assessment variables that affect loss to harvest are timing, location, method, and rate of harvest, artificial production, and species interactions.

Loss to Predation

Loss to predation is a natural ecosystem function; however, loss may increase to adverse levels through changes in ecosystem structure that increase prey vulnerability or increase predator feeding efficiency. Increased prey vulnerability may also be associated with other ecosystem functions including loss to adverse water temperature conditions, diversion, change in water surface level, increased toxicant concentration, and fishing. Assessment variables considered in the assessment of loss to predation include artificial production and species interactions.

Loss to Transport

Loss to transport includes settling of planktonic eggs and the passive movement of eggs, larval, and juvenile fish to adverse habitats such as movement of juvenile chinook salmon from the Sacramento River along the Delta Cross Channel and Georgiana Slough pathways. Assessment variables that increase or decrease loss to transport include flow, diversions, barriers, physical habitat, and species interactions.

Loss to Attraction

Loss to attraction is closely related to loss to transport. Loss to attraction applies to active movement of organisms, whereas loss to transport applies to the passive movement of organisms. Loss to attraction includes loss of organisms from active movement into unproductive habitat, delay of active movement out of unproductive habitat, or delay of active movement into habitat essential for completion of their life cycle. The assessment variables considered in assessing loss to attraction are flow, diversion, barriers, physical habitat, water quality, and species interactions.

Provision of Habitat

Provision of habitat includes providing physical, chemical, and biological conditions that support essential activities including spawning, feeding, respiration, growth, predator avoidance, and resting. Assessment variables that affect provision of habitat include flow, reservoir water elevation, temperature, substrate, barriers, physical habitat, water quality, and species interactions.

Foodweb Support

The foodweb is essential to maintaining species diversity, abundance, and distribution within an aquatic community. Foodweb support depends on factors affecting nutrient availability, production of food, and availability of food. Assessment variables that affect these factors include flow, reservoir water elevation, temperature, substrate, diversion, barriers, physical habitat, water quality, species interactions, and artificial production.

Access to Connected Habitats

Access to connected habitats includes physical, chemical, and biological conditions that support the essential movement (passive or active) of organisms to meet their specific needs for spawning, feeding, rearing, metabolic efficiency, and avoidance of predators. Access to connected habitats may depend on conveyance, pathways, and environmental cues. Assessment variables that affect these factors include flow, reservoir water elevation, temperature, barriers, physical habitat, water quality, and species interactions.

Support of Life-History Diversity

Species life-history diversity includes the needs and opportunities of a species or group of species to complete its life cycle. Greater life-history diversity enables species to survive and maintain productivity during natural and human-caused changes in environmental conditions. Assessment variables that affect life-history diversity include artificial production and the combined response to all other ecosystem functions.

AQUATIC COMMUNITIES

Aquatic communities are divisions of the aquatic ecosystem that consist of the connected sequences of water bodies through which aquatic species pass as they complete their life cycles. The definition of aquatic communities assisted the team in identifying geographic regions that were important to various species, grouping species for programmatic impact analysis, and evaluating the potential impacts of the alternatives to fish and the aquatic ecosystem. The assessment methods team agreed on dividing the aquatic ecosystem into five communities based on occurrence of fish and invertebrate species and on habitat conditions that could be affected by CALFED actions.

- **The reservoir community** includes habitat within Central Valley reservoirs. The impact assessment will focus on the major downstream reservoirs on Central Valley rivers (e.g., Shasta and Folsom Lakes and Lake Oroville). The potential effects on reservoirs farther upstream (and the associated stream reaches between reservoirs) will be acknowledged but will not be evaluated in detail. Upstream reservoir operations are unlikely to be described in the Programmatic EIR/EIS, and site-specific environmental documentation of potential effects on specific upstream reservoirs may be required during implementation of project-specific CALFED actions.

- **The coldwater riverine community** encompasses the stream and river reaches below the downstream reservoirs and provides spawning habitat for chinook salmon. The habitat is accessible to chinook salmon and meets the species' habitat needs, as defined by velocity, depth, substrate size, and adequate water temperature for spawning and incubation. The coldwater riverine community includes small tributary streams (e.g., Mill, Battle, and Clear Creeks) and portions of major rivers (e.g., the Feather, Yuba, Sacramento, and Tuolumne).

- **The warmwater riverine community** is located in the river reaches downstream of the coldwater riverine community and extends to the upstream edge of the Sacramento-San Joaquin Delta. In general, the warmwater riverine community includes portions of major rivers (e.g., the Feather, Yuba, Sacramento, and Tuolumne).

- **The estuarine community** extends from the downstream edge of the warmwater riverine community to the upstream edge of the marine community and includes tidally influenced habitat ranging in salinity from 0 to 10 parts per thousand (ppt). The estuarine community includes the Sacramento-San Joaquin Delta and usually includes most of Suisun Bay and Suisun Marsh.

- **The marine community** extends from the downstream edge of the estuarine community to the Golden Gate Bridge in tidally influenced habitat with salinity exceeding 10 ppt. The marine community includes San Francisco Bay and usually includes San Pablo Bay.

With the exception of the reservoir community, the geographic boundaries between these aquatic communities are not clearly defined. Under varying hydrologic and meteorologic conditions, the upstream and downstream boundaries shift. During wet years, the downstream boundaries of all communities (except the reservoir community) shift toward San Francisco Bay. During dry years, the downstream boundaries shift upstream toward dams or headwaters. Additional division of the aquatic communities into specific rivers and streams may be required to address specific actions included in the CALFED alternatives.

SELECTION OF REPRESENTATIVE SPECIES

Representative species populations provide an important cross section of aquatic ecosystem values potentially affected by CALFED actions. Each species and life stage responds differently to change in an assessment variable. A representative group of fish and other aquatic species was selected by the assessment methods team based on the importance of the species and their response to the assessment variables that could be affected by CALFED actions. Twenty-five species were selected for inclusion in the impact analysis, 18 species of fish and seven species or groups of invertebrates (Table 1). Although chinook salmon is identified as a single species in Table 1, it will be treated as multiple species (fall, late fall, winter, and spring runs) based on migration timing and geographic isolation.

Table 1. Species Selected for Inclusion in the Fish Impact Assessment

Species (Common/Scientific Name)		Aquatic Community: Reservoir	Coldwater	Warmwater	Estuarine	Marine
Fish						
Rainbow trout	*Oncorhynchus mykiss*	X				
Largemouth bass	*Micropterus salmoides*	X			X	
White sturgeon	*Acipenser transmontanus*		X	X	X	X
Chinook salmon	*Oncorhynchus tshawytscha*		X	X	X	X
Steelhead trout	*Oncorhynchus mykiss*		X	X	X	
Sacramento squawfish	*Ptychocheilus grandis*		X	X		
American shad	*Alosa sapidissima*			X	X	
Sacramento blackfish	*Orthodon microlepidotus*			X	X	
Sacramento splittail	*Pogonichthys macrolepidotus*			X	X	
Striped bass	*Morone saxatilis*			X	X	X
Smallmouth bass	*Micropterus dolomieui*			X		
Tule perch	*Hysterocarpus traskii*			X	X	
Delta smelt	*Hypomesus transpacificus*				X	
Longfin smelt	*Spirinchus thaleichthys*				X	X
White catfish	*Ictalurus catus*				X	
Inland silverside	*Menidia audens*				X	
Pacific herring	*Clupea harengeus pallasii*					X
Starry flounder	*Platichthys stellatus*					X
Invertebrate						
Terrestrial invertebrates			X	X	X	
Other aquatic invertebrates			X	X		
Rotifers	Rotifera				X	
Native mysid shrimp	*Neomysis mercedis*				X	
Crayfish	*Pacifastacus leniusculus*			X	X	
Asian clam	*Potamocorbula amurensis*				X	X
Bay shrimp	*Crangon franciscorum*					X

Species importance and species response to potential change in the assessment variables were considered in selecting representative species. A species was considered important if it met any of the following criteria:

- supports a commercial fishery,
- supports a sport fishery,
- is listed under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA), or
- has a significant ecological role.

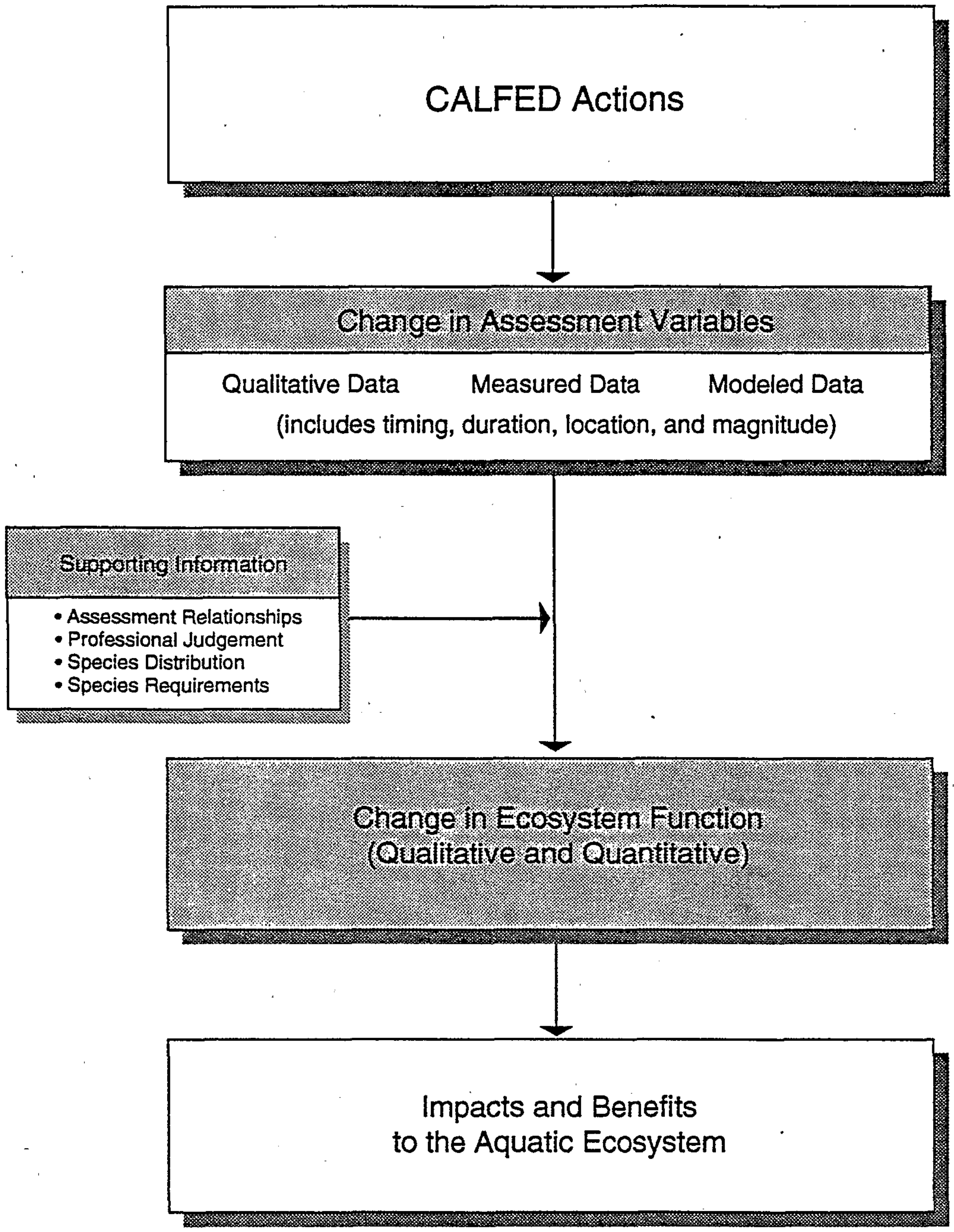
Species support commercial and sport fisheries if they are currently part of the sport or commercial catch. Species listed under ESA and CESA include species listed as threatened or endangered, species proposed for listing as threatened or endangered, and species of special concern.

Species designated as having a "significant ecological role" generally refers to species that have substantial direct effects on other species or respond to change in an assessment variable not reflected by the response of other species in the aquatic community. Effects on other species can include importance in foodweb support, effects on habitat availability, and effects on physical or chemical habitat conditions. For example, the Asia clam has a significant ecological role because of its probable effects on phytoplankton and zooplankton abundance. Sacramento squawfish has a significant ecological role because of its predation on juvenile chinook salmon.

ASSESSMENT METHOD

This section describes the general assessment method and relationships selected for inclusion in the programmatic impact assessment for fish and aquatic resources (Figure 2). As described previously, CALFED actions affect the assessment variables that drive the ecosystem functions which in turn have direct relevance to impacts and benefits to fish and other biotic elements of the aquatic ecosystem.

Changes to the assessment variables attributable to CALFED actions will be described using qualitative, measured, and modeled data. Qualitative data will include general descriptions of the effects of CALFED actions on the assessment variables. These descriptions rely on professional judgement. Measured data will be available for some assessment variables. For example, the number of acres of shallow-water habitat may be available for specific areas. CALFED actions may identify additions to existing shallow-water habitat. Modeled data refers to simulation of assessment variables under conditions that vary by alternative. Modeled data may be used for flow, reservoir surface elevation, diversion, and other variables.



CALFED BAY-DELTA PROGRAM

Figure 2
General Assessment Method for Fish and the Aquatic Ecosystem

The assessment variables drive the ecosystem functions. The affect of change in the assessment variables on ecosystem functions is evaluated by applying assessment relationships described under each function in Appendix A. Applying assessment relationships incorporates information on species and life-stage distribution and life-history requirements. Applicability of assessment relationships also relies on professional judgement.

Assessment relationships included in the assessment method and identified for each ecosystem function are presented in Appendix A. The discussion of aquatic communities, representative species, ecosystem functions, and assessment variables provided the foundation for selection of relationships used in the assessment method. The fish assessment methods team considered the following criteria in preliminary selection of assessment relationships:

- assessment relationships must represent an ecosystem function and describe a response to change in assessment variables,
- the assessment relationships are supported by current and historical data or professional judgement,
- the assessment relationships are consistent when extended beyond current and historic conditions,
- accuracy and precision of input information and the relationships enable qualitative comparison of the alternatives at the programmatic level of analysis, and
- the assessment relationships can be applied to all alternatives and provide a fair and consistent evaluation of the alternatives.

The applicability of the assessment relationships and need for additional or modified relationships will be reevaluated during development of the Programmatic EIR/EIS alternatives.

The change in ecosystem functions depicted by the application of assessment relationships will be integrated for all functions and species to qualitatively determine the adverse and beneficial impacts of CALFED actions to fish and the aquatic ecosystem and to distinguish differences between alternatives in the Programmatic EIR/EIS.

C-045188

APPENDIX A. RELATIONSHIPS FOR FISHERIES AND THE AQUATIC ECOSYSTEM ASSESSMENT

ECOSYSTEM FUNCTION:

LOSS TO ADVERSE WATER TEMPERATURE

ASSESSMENT VARIABLES:

- reservoir surface elevation
- water temperature (as affected by flow, reservoir operations, reservoir storage, and physical habitat including riparian, watershed, and floodplain restoration)
- physical habitat
- flow

ASSESSMENT RELATIONSHIPS:

1) water temperature changes that occur within the range between the optimal and lethal temperatures for a species are assumed to cause changes in mortality or spawning success.
   Measured indicators: **mortality; spawning success**

2) riparian restoration actions reduce water temperature and reduce fish losses to adverse water temperature.
   Measured indicators: **length of restored habitat**

3) increased temperature of reservoir releases from August through October increase losses to adverse water temperature in the river reaches below these reservoirs.
   Measured indicators: **reservoir surface elevation or temperature of released water**

4) reduced river flows from late May through October increase water temperatures and result in fish losses.
   Measured indicators: **river flow**

Species	Life Stage: Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
White sturgeon		●			
Chinook salmon	●	●	●	●	●
Steelhead trout	●	●	●	●	●
American shad		●			
Striped bass		●			

DISCUSSION: QUALIFIERS AND CAUTIONS

Information concerning temperature duration, location, and timing is needed.

Professional judgement about air temperature, flow, riparian habitat, habitat diversity, channel configuration may be the only available methods for estimating temperature on some streams.

Species- and life-stage-specific temperature-mortality and temperature-spawning relationships may need to be incorporated into the temperature evaluation together with professional judgement.

Attempting to manage stream temperature may affect other ecosystem functions.

Loss to adverse water temperature is linked to foodweb support: temperature can have important effects on food supply.

Loss to adverse water temperature is linked to provision of habitat: increase of shallow-water habitat may increase temperature in the Delta.

Adverse temperature may have indirect or secondary effects on fish by increasing susceptibility to disease or predation.

Factors beyond human control that affect temperature such as air temperature should be considered.

Effects of Delta storage and offstream storage on temperature need to be considered.

ECOSYSTEM FUNCTION:

LOSS TO DIVERSION

ASSESSMENT VARIABLES:

- physical habitat
- diversions
- barriers
- species interactions
- flow

ASSESSMENT RELATIONSHIPS:

1) fish screens and fish screen improvements reduce entrainment and impingement and reduce diversion loss.
   Measured indicators: **proportion of diverted flow with fish screens**

2) increased diversion or the proportion of flow and channel volume diverted increases diversion loss.
   Measured indicators: **diversion volume, channel volume, net flow, and tidal flow**

3) upstream relocation of X2 increases diversion-related losses.
   Measured indicators: X2

4) predator removal at diversion facilities reduces diversion loss.
   Measured indicators: **location and number of diversions with predator removal programs or programs to redesign facilities to reduce prey vulnerability**

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
White sturgeon			●	●	●
Chinook salmon			●	●	●
Steelhead trout			●	●	●
American shad		●	●	●	●
Sacramento splittail	●			●	●
Striped bass		●	●	●	●
Delta smelt	●		●	●	●
Longfin smelt	●		●	●	●
White catfish				●	
Rotifers			●	●	
Native mysid shrimp			●	●	

DISCUSSION: QUALIFIERS AND CAUTIONS

Information on diversion location, duration, timing, and size may be needed. Distance of diversion opening from main flow, vertical location of diversion opening, and screen type and efficiency may be important. Information on fish location and timing of movements (diurnal and seasonal) may be needed.

Removing diversions reduces fish loss. Proportionally more fish are lost at larger diversions. With multiple diversions, there is operational flexibility if the location of the fish is known. Velocity near diversions may be important to consider.

In the Delta, entrainment of fish is more important than diversion. Salinity may affect loss to diversion. Also, timing may be more critical for Delta species and diversion volume less critical.

If reconfiguration of Delta flows occurs under CALFED, then fundamental flow relationships may change. Models measuring hydraulics or particle-tracking models may provide useful information.

Use of size criteria rather than species or life-stage criteria may be better for estimating screen efficiency and probability of entrainment. At locations where screens are not efficient, other options should be considered.

Depending on changes in Delta configuration, diversion location, habitat restoration and loss to diversion may be important to additional species including Sacramento blackfish, tule perch, and others.

ECOSYSTEM FUNCTION:

LOSS TO CHANGE IN WATER SURFACE LEVEL

ASSESSMENT VARIABLES:

- substrate
- physical habitat
- species interactions
- flow

ASSESSMENT RELATIONSHIPS:

In streams:

1) decrease in water surface level dewaters nests and desiccates eggs.
   Measured indicators: **change in wetted habitat area; actions implemented to reduce short-term flow fluctuation; flow volume**

2) decrease in water surface level reduces intragravel flow, causing adverse dissolved oxygen levels or conditions conducive to predation or disease.
   Measured indicators: **change in wetted habitat area; actions implemented to reduce short-term flow fluctuation; flow volume**

3) decrease in water surface level strands juvenile and adult fish in habitat disconnected from the main river where temperature, dissolved oxygen levels, and other factors cause mortality.
   Measured indicators: **change in wetted habitat area; actions implemented to reduce short-term flow fluctuation; flow volume**

4) decrease in water surface level forces juvenile fish into less-optimal habitat where food may be less available and vulnerability to predation may increase.
   Measured indicators: **change in wetted habitat area; actions implemented to reduce short-term flow fluctuation; flow volume**

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
Rainbow trout		●	●	●	
Largemouth bass		●	●	●	
Chinook salmon	●	●	●	●	●
Steelhead trout	●	●	●	●	●
Sacramento splittail	●	●	●		
Smallmouth bass		●			

In reservoirs:

1) decrease in water surface level dewaters nests and desiccates eggs.
   Measured indicators: **change in wetted habitat area; reservoir surface elevation**

2) decrease in water surface level increases predation and causes movement to less-optimal habitat.
   Measured indicators: **change in wetted habitat area; reservoir surface elevation**

DISCUSSION: QUALIFIERS AND CAUTIONS

Information on location, duration, timing, and magnitude of surface level change may be needed.

In general, the longer water surface level is maintained at a stable level, the better. How release of water is accomplished may be important.

Stranding of larvae, juveniles, and adults is a major negative effect of surface level change.

Loss to change in water surface level is linked to provision of habitat: habitat restoration to reduce fish loss could include change in channel configuration or change in floodplain structure.

Maintenance of water level in streams and reservoirs especially would benefit species that spawn in shallow water.

ECOSYSTEM FUNCTION:

LOSS TO TOXICANTS

ASSESSMENT VARIABLES:

- water quality
- flow

ASSESSMENT RELATIONSHIPS:

1) reduced flow (dilution) increases toxicant concentration.
   Measured indicators: **flow volume**

2) increased input of toxicants increases toxicant concentration.
   Measured indicators: **agricultural acreage; agricultural return flow; programs to reduce municipal, industrial, and agricultural toxicant inputs**

DISCUSSION: QUALIFIERS AND CAUTIONS

Information on location, duration, timing, and magnitude of toxicant concentrations may be needed.

Chemical interactions (e.g., combining into more-toxic byproducts) may increase the negative effects of toxicants. Conversely, some compounds and metals, like copper, go out of solution more readily than others.

Crop types may be important when considering agricultural return flows. After spring rains, higher flows may increase the input of pesticides from agricultural lands.

Resuspension and release of toxicants resulting from dredging/disturbance of sediments may need to be considered.

Loss to Toxicants is linked to provision of habitat: restoration of riparian, floodplain/wetland, and margin areas may decrease toxicant loads.

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
All Species	●	●	●	●	●

Species- and life-stage-specific ranges of toxicity may need to be identified. There needs to be a reasonable understanding of toxicant levels and fish mortality/vulnerability relationships. Loss to toxicants should include sub lethal effects such as reduced reproductive success. Effects on foodwebs and bioaccumulation may need to be considered.

ECOSYSTEM FUNCTION:

LOSS TO PREDATION

ASSESSMENT VARIABLES:

- reservoir elevation
- diversion
- barriers
- physical habitat
- species interactions
- artificial production
- flow

ASSESSMENT RELATIONSHIPS:

1) increased predator habitat increases predation-related mortality.
   ***Measured indicators:* predator habitat availability**

   Note: Most loss-to-predation issues are addressed under other functions, including loss to diversion, loss to water surface level change, and loss to transport.

DISCUSSION: QUALIFIERS AND CAUTIONS

Information on predator size and association with prey (location/timing) may be needed.

Non-native species may be especially important in predator-prey interactions.

Loss to predation is linked to support of life-history diversity: the hatchery stocking program for striped bass constitutes a predator source.

Reducing the number of predatory fish may not uniformly be considered beneficial because they are often targeted for fishing.

Species	Life Stage: Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
Chinook salmon		●	●	●	●
Steelhead trout		●	●	●	●
American shad				●	●
Sacramento splittail	●	●	●	●	●
Striped bass		●	●	●	
Tule perch				●	
Delta smelt	●	●	●	●	●
Longfin smelt	●	●	●	●	●
Inland silverside		●	●	●	
Rotifers			●	●	
Native mysid shrimp			●	●	

ECOSYSTEM FUNCTION:

LOSS TO HARVEST

ASSESSMENT VARIABLES:

- harvest

ASSESSMENT RELATIONSHIPS:

1) increased fishing increases harvest mortality.
   ***Measured indicators:* harvest mortality rate; change in fishing regulations**

DISCUSSION: QUALIFIERS AND CAUTIONS

Loss to harvest is linked to support of life-history diversity: increase in hatchery production may increase harvest rates.

The harvest rates of natural - versus hatchery produced fish need to be considered.

Knowledge of age structure of populations, stock-recruitment relationships, expected future yields, and poaching rates may be necessary to conduct a meaningful impact assessment.

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
Rainbow trout				●	
Largemouth bass				●	
White sturgeon				●	
Chinook salmon	●			●	
Steelhead trout	●			●	
Sacramento squawfish				●	
American shad	●				
Sacramento blackfish				●	
Sacramento splittail	●			●	
Striped bass	●			●	
Smallmouth bass				●	
Pacific herring	●				
Crayfish				●	

ECOSYSTEM FUNCTION:

LOSS TO TRANSPORT

ASSESSMENT VARIABLES:

- barriers
- diversions (including location and operation)
- physical habitat
- flow

ASSESSMENT RELATIONSHIPS:

1) reduced river flow during planktonic egg and larval transport increases mortality.
   Measured indicators: **flow; transport rate**

2) flow toward adverse habitats during planktonic egg and larval transport and during downstream migration of juveniles increases mortality.
   Measured indicators: **net flow in the Delta Cross Channel, Georgiana Slough, and Old River**

3) flow through, over, or around barriers during the downstream migration of juveniles increases mortality.
   Measured indicators: **number of barriers removed, modified, or reoperated; location and number of barriers with predator removal programs; programs to redesign facilities to reduce prey vulnerability**

Species	Life Stage: Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
White sturgeon			●		●
Chinook salmon					●
Steelhead trout					●
American shad		●	●		●
Striped bass		●	●		
Delta smelt			●		
Longfin smelt			●		
Rotifers			●	●	
Native mysid shrimp			●	●	

DISCUSSION: QUALIFIERS AND CAUTIONS

Information concerning duration, location, timing, and magnitude of fish outmigration and flow is needed.

Effect of pulse flows needs to be evaluated.

Loss to transport is linked to provision of habitat: changing flow patterns may change habitat in the Delta. Increased habitat and/or facility isolation may reduce transport problems. Natural hydrology should be imitated wherever possible.

Insufficient flow can increase juvenile salmonid migration time; this may decrease survival. The effects of reverse flow in the Delta are uncertain. Fish response to net channel flow in the Delta is poorly understood.

If reconfiguration of Delta flows occurs under CALFED, then fundamental flow relationships may change. Models measuring hydraulics or particle-tracking models may provide useful information.

Ecosystem Function:

Loss to Attraction

Assessment Variables:

- water quality
- flow

Assessment Relationships:

1) presence of inappropriate flow-related cues such as agricultural return flow, river flow and water temperature during migration increases mortality.
   ***Measured indicators:* flow volume; number of barriers constructed to block migration**

2) absence of appropriate flow-related cues including pulse flows, turbidity and water temperature during migration increases mortality.
   ***Measured indicators:* flow volume; net channel flow toward Suisun Bay**

Discussion: Qualifiers and Cautions

Information concerning duration, location, timing, and magnitude of fish outmigration and flow are needed.

Loss to attraction is linked to provision of habitat: changing flow patterns may change habitat in the Delta. Increased habitat and/or facility isolation may reduce transport problems. Effect of pulse flows needs to be evaluated. Natural hydrology should be imitated wherever possible.

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
Chinook salmon	●		●	●	●
Steelhead trout	●		●	●	●
American shad	●				
Striped bass			●	●	●
Delta smelt			●	●	
Longfin smelt			●	●	

Insufficient flow can increase juvenile salmonid migration time; this may decrease survival. The effects of reverse flow in the Delta are uncertain. Fish response to net channel flow in the Delta is poorly understood.

If reconfiguration of Delta flows occurs under CALFED, then fundamental flow relationships may change. Models measuring hydraulics or particle-tracking models may provide useful information.

ECOSYSTEM FUNCTION:

PROVISION OF HABITAT

ASSESSMENT VARIABLES:

- reservoir surface elevation
- temperature
- substrate
- physical habitat
- flow

ASSESSMENT RELATIONSHIPS:

1) restoring riparian, channel, floodplain, and shallow-water habitat (Delta and Bay) increases spawning and rearing habitat availability.
   Measured indicators: **area or length of habitat; proportional change in habitat area or length**

2) extending low water temperatures downstream increases spawning and rearing habitat availability.
   Measured indicators: **area or river length meeting optimal temperature needs of salmon and steelhead; proportional change in area or length of habitat**

3) increases in flow generally increase spawning and rearing habitat availability.
   Measured indicators: **flow volume**

4) downstream shift of X2 salinity increases rearing habitat availability.
   Measured indicators: **area meeting optimal salinity needs for selected species; X2**

5) higher reservoir surface elevation increases spawning and rearing habitat availability.
   Measured indicators: **reservoir elevation-habitat relationships; reservoir surface elevation**

DISCUSSION: QUALIFIERS AND CAUTIONS

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
All species	●	●	●	●	●

Weighted usable area (WUA) will provide a general indication of whether flow increases or decreases are beneficial or detrimental.

Flow volume may be coupled with habitat restoration actions. Functioning floodplains, sediment sources, and scour points need to be considered. Effects of flow other than volume (e.g., undercut banks) also need to be considered. Restrictions on channel maintenance such as debris removal could be incorporated into habitat restoration actions.

The location of habitat restoration in the Delta, including geographic location of shallow-water habitat, substrate and water velocity may be important.

Erosion/deposition can affect habitat and should be considered. In addition to riparian areas, upland zones can affect aquatic habitat, illustrating the importance of considering habitat interactions in the assessment.

In reservoirs, habitat is linked to water surface level and slope of reservoir basins.

ECOSYSTEM FUNCTION:

FOODWEB SUPPORT

ASSESSMENT VARIABLES:

- reservoir surface elevation
- diversions
- barriers
- physical habitat
- water quality
- species interactions
- flow

ASSESSMENT RELATIONSHIPS:

1) reducing short-term water surface level fluctuation increases food production in rivers and reservoirs.
   Measured indicators: **flow; reservoir surface elevation; actions implemented to reduce short-term flow fluctuation**

2) increasing flow increases food organism habitat in rivers and in the Sacramento-San Joaquin Delta estuary (i.e., related to estuarine salinity).
   Measured indicators: **wetted area; flow volume; X2**

3) adding and improving riparian, floodplain, channel, and shallow-water habitat increases food organism production in rivers and the Sacramento-San Joaquin Delta estuary.
   Measured indicators: **area and length of habitat; proportional change in habitat area or length**

4) reducing toxicant concentrations increases food organism survival in all habitats.
   Measured indicators: **see indicators for "Loss to Toxicants"**

5) reducing diversions and net channel flow toward diversions reduce food organism entrainment losses in the Sacramento-San Joaquin Delta estuary.
   Measured indicators: **diversion volume, net channel flow toward diversions**

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
All species	●		●	●	●

6) increasing reservoir surface levels increases food availability.

Measured indicators: **reservoir surface elevation**

DISCUSSION: QUALIFIERS AND CAUTIONS

Non-native species can greatly affect foodweb support (e.g., Asia clam).

In the Delta, water residence time may affect phytoplankton production and the foodweb. Changes in Delta hydraulics can affect habitat and water circulation, which may affect food organisms.

In general, food production is related to volume, surface area, and water level; however, erosion and deposition may affect habitat quality for food organisms.

In reservoirs, drawdown duration, timing, and magnitude can affect foodweb support.

ECOSYSTEM FUNCTION:

ACCESS TO CONNECTED HABITATS

ASSESSMENT VARIABLES:

- temperature
- barriers
- physical habitat
- water quality
- flow

ASSESSMENT RELATIONSHIPS:

1) removing or modifying physical barriers provides access to habitat.
   Measured indicators: **number of barriers removed, modified , and reoperated; change in availability of accessed habitat**

2) flow provides environmental cues and physical and chemical conditions that improve access to habitat.
   Measured indicators: **flow volume, water quality**

DISCUSSION: QUALIFIERS AND CAUTIONS

Clearer understanding of flow patterns in the Delta may be needed. Trucking of juvenile salmonids, flow, and Delta exports may affect straying.

Barriers affect hydraulics, which could affect migration patterns through the Delta. Operation of Montezuma Slough gates may affect movement through Suisun Marsh.

In reservoirs, drawdown may impede access of rainbow trout to their spawning streams.

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
Rainbow trout	●				
White sturgeon	●				
Chinook salmon	●				
Steelhead trout	●				
American shad	●				
Sacramento splittail	●				

ECOSYSTEM FUNCTION:

SUPPORT OF LIFE HISTORY DIVERSITY

ASSESSMENT VARIABLES:

- artificial production
- combined response to all other ecosystem functions
- species interactions

ASSESSMENT RELATIONSHIPS:

1) increased artificial production increases population abundance.
Measured indicators: **number of hatchery fish produced; change in hatchery production goals; change in harvest**

2) increased artificial production reduces species fitness.
Measured indicators: **proportion of population composed of artificially-produced individuals**

3) species introductions reduce life-history diversity of native species.
Measured indicators: **actions to limit species introductions**

DISCUSSION: QUALIFIERS AND CAUTIONS

Reduced hatchery production may increase natural population abundance. Conversely, increase in number of hatchery fish may decrease natural population abundance. Impacts on the total population and natural proportion of the population need to be considered.

Current hatchery operations are detrimental to wild stocks of chinook salmon and steelhead trout. Guidelines are needed to minimize impacts on wild fish/listed species. Hatchery fish may compete with wild fish.

There is a link between support of life history diversity and provision of habitat: new habitat could be utilized by hatchery-produced fish. Ocean harvest rates are driven by hatchery production.

Flow variability may benefit maintenance of life-history diversity.

Species	Life Stage				
	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration
All species	●	●	●	●	●

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